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Effects of speed display signs on driving speed at pedestrian crossings on collector streets

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ABSTRACT

This study was designed to evaluate the short- and long-term effects of speed display signs on driving speed at pedestrian crossings in a low-speed (40 km/h) urban environment. Driving speeds were compared 1 week before installation, after installation (1 week; 1 month; 3 months; 5 months) and 1 week after removal. The main results showed that the speed displays decreased the mean speed by 0.5–2.9 km/h, which translates to a 4–22% drop in pedestrian fatality risk. Furthermore, there was a drop in the proportion of speeding vehicles and approaching speed of individual vehicles. The decrease in speed persisted over time, suggesting that speed displays may reduce speeds in the long term. In conclusion, installing speed displays at pedestrian crossings on collector streets reduces driving speeds and could contribute to the safety of pedestrians.

1. Introduction

Reducing driving speeds has been recognised as the one of the main measures for improving traffic safety for all types of areas and road users (Adminaité-Fodor & Jost, 2019, 2020; Elvik, Vadeby, Hels, & van Schagen, 2019; Johansson, 2009). For example, the risk of a pedestrian being killed is almost five times higher in a collision at 50 km/h than at 30 km/h (Kröyer et al., 2014).

Driving speeds can be reduced by different measures such as improving the built environment (e.g. Agerholm et al., 2017), lowering speed limits (e.g. Elvik et al., 2019) or providing information to the driver through in-vehicle (e.g. Lai & Carsten, 2012) or roadside systems (e.g. Hakkert et al., 2002; Vignali et al., 2019). One example of roadside systems is speed displays, which are interactive signs showing a vehicle's approaching speed. Their main purpose is to inform the driver of their actual speed and thus improve adherence to the set limit and reduce speeding. Speed display signs have been assessed to reduce mean speed and the proportion of vehicles exceeding the speed limit in speed transition zones (Ullman & Rose, 2005), horizontal curves (Ullman & Rose, 2005), work zones (Mattox et al., 2007), school zones (Lee et al., 2006; Williamson et al., 2016) and high-speed urban areas (Ardeshiri & Jeihani, 2014; Ullman & Rose, 2005).

Lately, they have also become common in low-speed urban areas, for example in Finland where the data for this study was collected. However, fewer studies are available on evaluating their effect in such areas. Walter & Broughton (2011) assessed the effects of short-term (0–3 weeks) installation of speed displays at 10 sites with speed limits of 30 mph (48 km/h). For vehicles travelling in free flow conditions at the speed display, they found an average drop in mean speed

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of 1.4 mph (2.3 km/h) and in the proportion of vehicles exceeding the speed limit of 12 percentage points. Their results also showed that the corresponding overall mean speed dropped by 0.2 mph (0.3 km/h) 200 m after the speed display but increased by 0.6 mph (1.0 km/h) at 400 m, indicating that the effectiveness range might be quite short. Gehlert et al. (2012) compared different types of speed displays (verbal coloured, numeric coloured and numeric) on a low-speed urban street and found that the mean speed dropped by 0.7–3.1 km/h and the proportion of vehicles exceeding the speed limit dropped by 7–29 percentage points when the speed display was installed for 2–3 months. Once the speed display was removed, the mean speed returned towards the initial values (Gehlert et al., 2012; Walter & Broughton, 2011).

Given the low number of studies conducted in low-speed urban areas, this study was designed to examine the short- and long-term effects of speed displays on driving speeds at pedestrian crossings on urban streets with low speed limits (40 km/h). The study focused on the short- and long-term effects of speed displays while installed and their effect immediately (3 days) after removal. The long-term effects after removal were not included in the study. Furthermore, the implications on traffic safety were assessed based on the observed speed changes.

2. Method

2.1. Speed displays

The speed display sign used in the study was 63.4 cm wide and 78.6 cm high, with a black background and red-and-white dashed border as shown in Fig. 1. The text "SINÄ AJAT" (Finnish for "You are driving") was printed in yellow, and below it appeared the measured speed alternating with a smiley face. If the speed limit was not exceeded, the numeric display was yellow and the smiley face green, both turning red when the speed limit was exceeded by up to 10 km/h. If the speed limit was exceeded by more than 10 km/h, a red encircled exclamation mark appeared instead.

2.2. Design and sites

The design was a before-after study with control sites. Speed effects were evaluated in two street environments — busy or quiet collector streets connecting local streets to arterial roads — each with two study sites (Busy 1, Busy 2, Quiet 1 and Quiet 2) in the cities of Lahti (population 120,000) and Tampere (population 240,000) in southern Finland. The study also included two control sites, one for each street environment. All sites were located on straight two-way street sections (5.5–8.5 m wide) with one lane per direction, no horizontal variation, and a posted speed limit of 40 km/h.

The speed displays were fixed to light poles 45–65 m before a pedestrian crossing on a straight road section. Driving speeds (spot speeds) were measured at two measurement points (MP), roughly 100 m before (upstream) and at (downstream) the pedestrian crossing. The sign was visible to approaching drivers at MP1. The study site layout is illustrated in Fig. 2. At the control sites, driving speeds were measured at a single MP roughly 100 m before the pedestrian crossing. The data was collected with radar sensors that continuously measure the speed and length of each passing object with microwave technology.

Driving speeds were measured in six phases: 1 week before installation, after installation (1 week; 1 month; 3 months; 5 months) and 1 week after removal. The speed displays were removed 3 days after the fifth measurement phase. Each phase lasted 1 week. The speed displays were activated right after installation and were in operation during May–October 2018. The average daily number of vehicles was 2,100 (Busy 1); 4,400 (Busy 2); 900 (Quiet 1) and 1,100 (Quiet 2). The difference in average daily number of vehicles by measurement phase ranged at the busy sites from 0 to 300 and quiet sites from 0 to 100. The daily number of pedestrians was not measured, but based on the cities' measurements it was estimated to range from 150 to 350 at all sites.

A trend correction based on the results collected at the control sites was first computed to eliminate seasonal variations in traffic. The trend correction constant was calculated for both control sites for each phase by comparing the mean speed of all vehicles with that during the first phase. Next, the trend correction for the respective control and phase was added to each speed observation at the study sites using the following formula:

$$v_{E,a} = \frac{1}{n}\sum_{i=1}^{n} u_{E,a} + \left(\mu_{C,a} - \mu_{C,b}\right)$$

where v is the corrected speed observation, u is the measured speed observation, μ is the mean speed of all vehicles, E is the experimental site, C is the control site, *b* the before phase and *a* the after phase.

Two speed analyses were conducted. The first one focused on total traffic flow and compared the speed behaviour of all vehicles at MP2 for all the phases after installation and removal with that before installation by calculating: (1) mean speed, (2) share of vehicles exceeding the speed limit and (3) share of vehicles exceeding the speed limit by more than 10 km/h. The effects on traffic safety were estimated by calculating the pedestrian fatality risk by applying Equation 2[1] in the study by Rosén & Sander (2009) to the mean speed of all vehicles downstream and comparing the change in risk between phases.

[1] $P(v) = \frac{1}{1+exp^{(6.9-0.090v)}}$, where v is impact speed

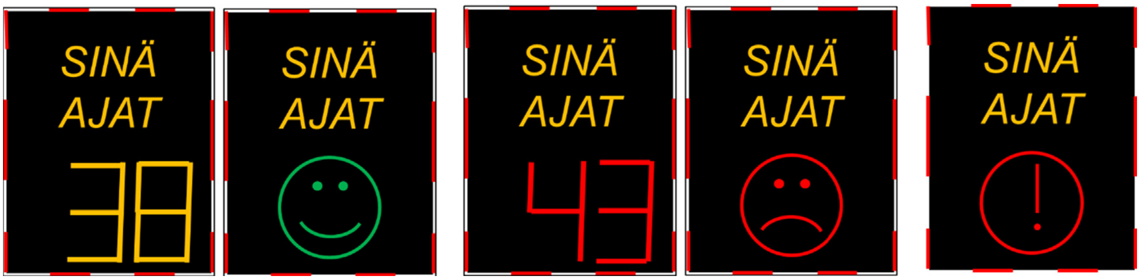

Fig. 1. Diagram of the speed display signs used in the study. "Sinä ajat" is Finnish for "You are driving".

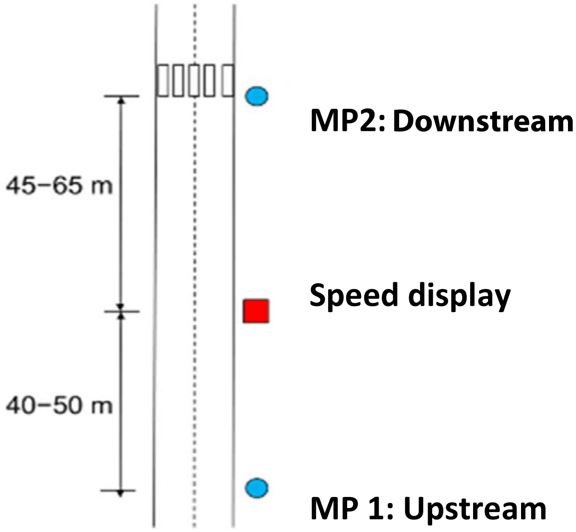

Fig. 2. Diagram of the study sites. Drivers approach the site from the bottom.

Secondly, we compared the speed change of individual drivers between measurement points by phase. For all sites, the data included a matched sample of vehicles travelling in free-flow traffic, i.e. with a headway of 6 s or more (Vogel, 2002). The computation was based on matching time stamp and estimated average speed change for the distance between the measurement points' datasets. The matched sample included on average 900–1,600 vehicles per day at the busy sites and 300–700 vehicles per day at the quiet sites.

3. Results

3.1. Spot speed and pedestrian fatality risk

The effects on mean speed, i.e. by comparison with the speed before installation, were computed with one-way ANOVA for all phases by site. There was a statistically significant effect on mean speed for all sites (Busy 1: $F(5, 88\ 521) = 91.9$, $p = .000$; Busy 2: $F(5, 183\ 318) = 733.1$, $p = .000$; Quiet 1: $F(5, 39\ 068 = 156.2$, $p = .000$ and Quiet 2: $F(5,43\ 142) = 186.2$, $p = .000$), and the effects can be classified as small ($\eta^2 < 0.06$).

Post hoc Dunnett C tests ($\alpha = 0.05$) showed that all the effects of the display sign were significant, except for 3 months after installation at the busy sites (Table 1). While the speed display was installed, the mean speed of all vehicles dropped by 1.5–2.9 km/h at quiet sites and 0.5–2.0 km/h at busy sites. One week after removal, the mean speed of all vehicles was 1.1–1.4 km/h lower at busy sites and 0.6–2.0 km/h lower at quiet sites.

The effects on proportion of vehicles exceeding the speed limit were tested with Chi-square tests including a Bonferroni adjustment. While the speed display was installed, the proportion of vehicles exceeding the speed limit dropped by −4…-17 percentage points at the quiet sites (Table 2). At the busy sites there was a significant effect 1 week and 1 month after installation, with a drop of 2 percentage points. One week after removal, the proportion of vehicles exceeding the speed limit was 1–4 percentage points lower, except at site Quiet 1 where it was 12 percentage points lower.

While the speed display was installed, the proportion of vehicles exceeding the speed limit by over 10 km/h dropped by −6…-10 percentage points at the quiet sites (Table 2). At the busy sites, the corresponding proportion varied by + 6…-14 percentage points. One week after removing the speed display, the proportion of vehicles exceeding the speed limit by more than 10 km/h dropped by 2–10 percentage points.

Table 1
Effect on mean speed (km/h) by site and measurement phase.

		Quiet 1	Quiet 2	Busy 1	Busy 2
Mean speed (km/h) before installation		44.9	43.6	46.1	46
Change in mean speed compared to before installation	1 week after	−1.5*	−2.9*	−1.2*	−1.5*
	1 month after	−2.8*	−2.7*	−0.5*	−2.0*
	3 months after	−2.1*	−2.2*	0.1	–
	5 months after	−2.7*	−1.5*	−0.8*	−1.8*
	After removal	−2.0*	−0.6*	−1.1*	−1.4*

* Statistically significant (α = 0.05).

Table 2
Effect on proportion of vehicles exceeding the speed limit and proportion of vehicles exceeding the speed limit by more than 10 km/h per site and measurement phase.

		Quiet 1	Quiet 2	Busy 1	Busy 2
Proportion of vehicles exceeding the speed limit before installation (%)		78	73	86	88
Change in proportion compared to before installation (percentage points)	1 week after	−12*	−17*	−2*	1
	1 month after	−18*	−11*	–	−2*
	3 months after	−14*	−11*	–	1
	5 months after	−12*	−4*	–	–
	After removal	−12*	−1*	−2*	−4*
Proportion of vehicles exceeding the speed limit by more than 10 km/h before installation (%)		19	16	24	24
Change in proportion compared to before installation (percentage points)	1 week after	−6*	−10*	−4*	−11*
	1 month after	−9*	−9*	−4*	−14*
	3 months after	−8*	−7*	6*	−3*
	5 months after	−9*	−6*	−4*	−13*
	After removal	−10	−2*	−7*	−10*

* Statistically significant (α = 0.05).

While the speed display was installed, the relative pedestrian fatality risk dropped by 12–22% at the quiet sites and 4–16% at the busy sites (except for 3 months after installation) (Table 3). One week after removal, the relative pedestrian fatality risk was 5–16% lower than before installation.

3.2. Individual speed behaviour

The effects on mean change in approaching speed of individual vehicles travelling in free flow traffic were computed with one-way ANOVA for all phases by site. There was a statistically significant effect on approaching speed for all sites (Busy 1: $F(5,44\,547) = 27.357$, $p = .000$; Busy 2: $F(5,63\,635) = 123.719$, $p = .000$; Quiet 1: $F(5,22\,275) = 34.449$, $p = .000$ and Quiet 2: $F(5,25\,203) = 37.771$, $p = .000$).

Post hoc Dunnett C tests ($\alpha = 0.05$) showed that the effects of the speed display were significant at three sites (Busy 1, Busy 2 and Quiet 2) for all phases while the speed display was installed (Table 4). The mean change in approaching speed dropped by 0.2–0.8 km/h at sites Quiet 2 and Busy 1 but increased by 0.4–1.2 km/h at site Busy 2. The drop in approaching speed was largest 1 week after installation. At site Quiet 1, the only significant effect on approaching speed was 5 months after installation with an increase of 0.2 km/h. One week after removal, the mean change in approaching speed was 0.3–0.7 km/h lower at sites Quiet 1, Quiet 2 and Busy 1.

Table 3
Impact on pedestrian fatality risk per site and measurement phase.

		Quiet 1	Quiet 2	Busy 1	Busy 2
Pedestrian fatality risk before installation		0.05	0.05	0.06	0.06
Change in pedestrian fatality risk compared to before installation (%)	1 week after	−12	−22	−10	−12
	1 month after	−21	−21	−4	−16
	3 months after	−16	−17	1	–
	5 months after	−21	−12	−7	−14
	After removal	−16	−5	−9	−11

Table 4
Mean change in approaching speed (km/h) of individual vehicles travelling in free flow traffic by site and measurement phase.

		Quiet 1	Quiet 2	Busy 1	Busy 2
Mean change in approaching speed (km/h) before installation		−0.8	0.6	−4.4	−1.9
Change in mean approaching speed compared to before installation (km/h)	1 week after	–	−0.8*	−0.6*	0.7*
	1 month after	−0.2	−0.5*	−0.4*	0.6*
	3 months after	–	−0.3*	−0.2*	0.4*
	5 months after	0.2*	−0.2*	−0.3*	1.2*
	After removal	−0.7*	−0.3*	−0.3*	−0.1

* Significantly different (α = 0.05) than before installation.

4. Discussion

This study was designed to examine the short- and long-term effects of speed displays on driving speeds on low-speed urban collector streets. The main speed analysis compared the spot speed of all vehicles at a pedestrian crossing. While the speed display was installed, the mean speed of all vehicles dropped by 0.5–2.9 km/h. The effect on the proportion of vehicles speeding was −17…+1 percentage points, and on the proportion of those speeding by more than 10 km/h −14…+6 percentage points. These findings are in line with previous studies (Gehlert et al., 2012; Walter & Broughton, 2011) investigating the short-term impact of speed displays. The discovered mean speed effects at the pedestrian crossing correspond to a 4–22% reduction in pedestrian fatality risk.

The second speed analysis compared the approaching speed of individual vehicles travelling in free flow traffic. While the speed display was installed, the approaching mean speed dropped by 0.2–0.8 km/h at two sites (Busy 1 and Quiet 2), increased by 0.4–1.2 km/h at one site (Busy 2) and mainly remained the same at one site (Quiet 1). Hence, speed displays have a lesser effect on drivers selecting their own driving speed than on the overall traffic flow. The results also show that the speed effects varied somewhat by site and phase, which is difficult to explain. These results imply that although the effects are generally positive, there is room for further research.

While the speed displays were installed, driving speeds remained lower over time, which suggests that speed displays can have a long-term impact on driving speeds. However, the mean speed exceeded the speed limit during all measurement phases. Regarding street type, driving speeds generally dropped more on quiet collector streets than on busy ones. Looking at the measurement phases, the effect of speed displays on the speed of all vehicles was least 3 months post-installation and on the approaching speed of individual vehicles greatest 1 week after installation.

One week after removing the speed displays, driving speeds were lower than before installation at the pedestrian crossing. This suggests that some speed reduction may occur after removal of the sign, but the long-term effects were not included in this study. Earlier studies have found that mean speeds trend back towards their initial values 2 weeks to 4 months after removal (Gehlert et al., 2012; Ullman & Rose, 2005; Walter & Broughton, 2011).

As with most field studies, the current study is subject to confounding factors, although we attempted to control and distinguish their effects. First, the analyses were based on trend-corrected speed observations to minimise the effects of any seasonal variations in traffic. This was done by using control sites with similar main characteristics of the physical environment (e.g. number of lanes, lane width, speed limit, horizontal variation) and weather conditions. Second, the effect of traffic volume seems to be small, since there was no large variation in the number of vehicles between measurement phases. Finally, due to the long evaluation period, the measurement phases differed in terms of lighting conditions (daytime varied between 11 and 19 h) and temperature (average temperature varied between 6 and 21 °C). However, the main characteristics of the most important driving-related weather conditions were similar (e.g. daily temperature above zero, no snowfall and no heavy rain), suggesting that they had no major impact on the results.

In conclusion, installing speed displays on low-speed urban streets significantly reduces the mean speed, proportion of speeding vehicles, and approaching speed at pedestrian crossings. The speed displays were installed for 5 months and the decrease in speed persisted over time, suggesting that speed displays may reduce speeds in the long term. The corresponding traffic safety potential of these speed effects could include up to a 20% reduction in pedestrian fatality risk. Future research should be done to confirm the traffic safety effects of speed displays, since this study assessed them indirectly.

Availability of data and material

The speed data used in this study were collected solely for the current study and are therefore not publicly available.

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CRediT authorship contribution statement

Fanny Malin: Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft. **Juha Luoma:** Conceptualization, Methodology, Writing - review & editing.

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